OBSERVATION OPTICAL DEVICE

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to an observation optical device, which has an observation optical system and a photographing optical system, and is constructed in such a manner that a focusing mechanism for the observation optical system and a focusing mechanism for the photographing optical system are operated in association with each other so that the observation optical system is utilized as a focusing device for the photographing optical system.

2. Description of the Related Art

As is well known, observation optical devices, such as binocular telescopes or monocular telescopes, are used for watching sports, wild birds, and so on. When using such a device, it is often the case that the user sees something that he or she would like to photograph. Typically, he or she will fail to photograph the desired scene because he or she must change a camera for the binocular telescope and during this time the chance is lost. For this reason, a binocular telescope containing a camera is proposed, whereby a photograph can be taken immediately by using the camera contained in the binocular telescope while continuing the observation through the binocular telescope.

For example, Japanese Unexamined Utility Model Publication (JUUMP) (KOKAI) No. 6-2330 discloses a binocular telescope with a photographing function, i.e., a combination of a binocular telescope and a camera, in which the camera is simply mounted in the binocular telescope. The binocular telescope is provided with a pair of telescopic optical systems for observing an observed object in an enlarged state, and a photographing optical system for photographing the observed image. Namely, in the binocular telescope with a photographing function, the pair of telescopic optical systems functions not only as a viewfinder optical system for the photographing optical system, but also as a telescopic binocular system.

Generally, in an observation optical system such as a binocular telescope or a monocular telescope, when the rear focal point of the objective lens system and the front focal point of the ocular lens system roughly coincide with each other, an observed object at infinity (i.e., distant view) can be observed in an in-focus state through the observation optical system. Accordingly, for observing an observed object at a shorter distance than infinity (i.e., close-range view) in an in-focus state, a focusing operation is needed for focusing on the close-range view. In such a focusing operation, the objective lens system and the ocular lens system are separated from the in-focus state of the distant

view. Therefore, in the observation optical system, a focusing mechanism is mounted, which moves the objective lens system and the ocular lens system to adjust the distance therebetween. Concretely, the focusing mechanism comprises a rotary wheel, disposed adjacent to the observation optical system, and a movement conversion mechanism for converting a rotational movement of the rotary wheel into a relative back-and-forth movement of the objective lens system and the ocular lens system.

In the binocular telescope with a photographing function disclosed in the above-described JUUMP '330, however, there is no description of the focusing operation of the pair of observation optical systems. Further, as described above, the pair of observation optical systems functions as a viewfinder optical system for indicating an observed range, and '330 does not indicate how the photographing optical system focuses on an object to be photographed.

USP No. 4,067,027 discloses another type of binocular telescope with a photographing function, which is provided with a pair of observation optical systems and a photographing optical system. In this binocular telescope with a photographing function, a focusing mechanism for the pair of observation optical systems is provided with a mechanism for performing a focusing operation of the photographing optical system. Namely, by rotating the rotary wheel of the focusing

mechanism manually, the objective lens system and the ocular lens system are moved relative to each other in each of the observation optical systems, which causes the photographing optical system to move relative to a surface of a silver halide film, and thus, the focusing operations are performed for the pair of observation optical systems and the photographing optical system. Thus, when an observed object is observed in an in-focus state through the pair of observation optical systems, the object is also in an in-focus state in the photographing optical system. Therefore, if a photographing operation is carried out when the observed object is observed in an in-focus state through the pair of observation optical systems, the object image is focused on a surface of the silver halide film.

When different users observe an observed object in an in-focus state through an observation optical device such as a binocular telescope or a monocular telescope, the observation optical system is not necessarily observed with the same dioptric power for each user. This is because, generally, when a human looks or observes through an optical instrument such as a telescope, the eye is apt to focus at -1D (diopter), which is known as instrument myopia, and human eyes have the ability to adjust, so that an object in a range from 15 cm to infinity ahead of the eyes can be focused. This ability to adjust depends upon the age of the observer, so

that the range in which the eyes can focus on an object is different depending upon the observer. Thus, even if the dioptric power of the observation optical system is offset from -1D (i.e., the instrument myopia), a human can still observe the observed object image through the observation optical system as a focused image. Therefore, in the binocular telescope with the photographing function described in USP '027, even if the observed object image is observed through the pair of observation optical systems in an in-focus state after manual operation of the rotary wheel, the observed object image is not necessarily focused by the photographing optical system.

To solve the problem described above, it is proposed in Japanese Examined Patent Publication (KOKOKU) No. 36-12387 that a reticle (or focusing index element) be movably provided at a position close to the front focal point of the ocular optical system of the observation optical system so that the observation optical system is always focused with a constant dioptric power. The reticle is an index having a proper shape (e.g., a cross) formed on a transparent glass plate, for example. If the index is provided in the ocular optical system of the observation optical system, the user can adjust the position of the index to correspond to a proper dioptric power, so that the index and the observed object can be observed simultaneously in an in-focus state. Namely, when

the user observes the object while adjusting the dioptric power to the index, the observed object is always observed with a constant dioptric power. Therefore, when the observation optical system reaches an in-focus state, the photographing optical system is adjusted in an in-focus state in association with the observation optical system. Thus, in the binocular telescope with a photographing function, the observation optical system can be utilized as a focusing device for the photographing optical system.

However, according to experimental results conducted by the inventors, although each user observes an observed object, the image of the observed object is formed close to the index in an in-focus state, and the position of the image of the observed object in the optical axis direction does not coincide with the optical position of the reticle. In other words, it turns out that each user does not observe the observed object with a constant dioptric power, in spite of the existence of the reticle. Thus, even if the observation optical system is set to an in-focus state, it is not guaranteed that the photographing optical system is set to an exact in-focus state, so that the photographed image may become unsharp.

SUMMARY OF THE INVENTION

Therefore, an object of the present invention is to provide an observation optical device, in which the

observation optical system is utilized as a focusing device of the photographing optical system, and the reliability of the focusing function is improved.

According to the present invention, an observation optical device with a photographing function, having an observation optical system and a photographing optical system is provided. The observation optical system is utilized as a focusing device for the photographing optical system. The observation optical device comprises a first focusing mechanism, a second focusing mechanism, an association mechanism, and a reticle.

The first focusing mechanism focuses the observation optical system so as to observe a close-range view through the observation optical system. The second focusing mechanism focuses the photographing optical system so as to photograph a close-range view through the photographing optical system. The association mechanism associates the first and second focusing mechanisms with each other in such a manner that both of the observation optical system and the photographing optical system are always kept in a focused state. The reticle is provided in the observation optical system for focusing the observation optical system with a predetermined dioptric power during an operation of the association mechanism. The second focusing mechanism is constructed in such a manner that a measured dioptric power

difference between a first dioptric power of a combination of an eye of the user and an ocular lens system of the observation optical system, focusing on the reticle, and a second dioptric power of a combination of the eye and the ocular lens system and an objective lens system of the observation optical system, focusing on an object to be observed, is cancelled.

The measured dioptric power difference may be obtained as an arithmetic mean of measured dioptric power differences obtained from experiments conducted on a plurality of observers.

Preferably, the association mechanism comprises a rotary wheel member having a manually operated rotary wheel. In this case the observation optical system comprises two optical system elements that are movable along the optical axis of the observation optical system to focus the observation optical system. The first focusing mechanism forms a first movement-conversion mechanism for converting a rotational movement of the rotary wheel member into a relative back-and-forth movement of the two optical system elements. The photographing optical system is movable relative to an imaging plane along the optical axis of the photographing optical system to focus the photographing optical system. The second focusing mechanism forms a second movement-conversion mechanism for converting a rotational

movement the rotary wheel member into a back-and-forth movement of the photographing optical system elements relative to the imaging plane.

The rotary wheel member may comprise a rotary wheel cylinder in which a lens barrel is housed so as to be movable along the central axis of the rotary wheel cylinder. The photographing optical system may be housed the lens barrel. In this case, the second movement-conversion mechanism comprises a first cam groove formed in one of the rotary wheel cylinder and the lens barrel, and a first cam follower formed in the other of the rotary wheel cylinder and the lens barrel. The first cam groove is formed in such a manner that a rotational movement of the rotary wheel cylinder is converted into a back-and-forth movement of the lens barrel along the central axis of the rotary wheel cylinder and the measured dioptric power difference is cancelled.

The first movement-conversion mechanism may comprise a second cam groove formed on an outer surface of the rotary wheel cylinder, an annular member that has a second cam follower that engages with the first cam groove and that is attached on an outer surface of the rotary wheel cylinder to move along the central axis of the rotary wheel cylinder, and a movement transmission mechanism that transmits the movement of the annular member to one of the two optical system elements of the observation optical system.

Preferably, the observation optical system forms a pair, so that the observation optical device functions as a binocular telescope with a photographing function.

In this case, the pair of observation optical systems is mounted on an optical system mount plate that comprises first and second plates that are movable relative to each other. One of the pair of observation optical systems is placed on the first plate, and the other of the pair of observation optical systems is placed on the second plate, so that the distance between the optical axes of the pair of observation optical systems is adjusted by changing the relative positions of the first and second plates.

The first and second plates may be linearly moved relative to each other, so that the optical axes of the pair of observation optical systems are moved in a predetermined plane, whereby the distance between the optical axes of the pair of observation optical systems is adjustable.

BRIEF DESCRIPTION OF THE DRAWINGS

The objects and advantages of the present invention will be better understood from the following description, with reference to the accompanying drawings in which:

Fig. 1 is a horizontal sectional view showing a binocular telescope with a photographing function, which is an embodiment of an observation optical device according to the present invention, in a state in which a movable casing

section is set at a retracted position;

Fig. 2 is a sectional view along line II-II of Fig. 1;

Fig. 3 is a horizontal sectional view similar to Fig. 1, the movable casing section being set at a maximum-extended position;

Fig. 4 is a horizontal sectional view similar to Fig. 2, the movable casing section being set at a maximum-extended position;

Fig. 5 is a plan view showing an optical system mount plate provided in a casing of the optical device shown in Fig. 1;

Fig. 6 is a plan view showing right and left mount plates which are disposed on the optical system mount plate shown in Fig. 5;

Fig. 7 is an elevational view observed along line VII-VII of Fig. 6, in which the optical system mount plate is indicated as a sectional view along line VII-VII of Fig. 5;

Fig. 8 is an elevational view observed along line VIII-VIII of Fig. 1;

Fig. 9 is a development showing helicoid cam grooves formed on an outer surface and an inner surface of a rotary wheel cylinder mounted in the binocular telescope with a photographing function;

Fig. 10 is a plan view showing a reticle provided in

a pair of telescopic optical systems;

Fig. 11 is an elevational view of the reticle view shown in Fig. 10;

Fig. 12 is a graph showing a result of a focusing test for the binocular telescope with a photographing function; and

Fig. 13 is a development similar to Fig. 9, and shows an example of how the helicoid cam groove for focusing the photographing optical system is changed based on the focusing test result shown in Fig. 12.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention will be described below with reference to the embodiments shown in the drawings.

Fig. 1 shows an internal structure of an observation optical device with a photographing function, to which an embodiment of the present invention is applied, the observation optical device being a binocular telescope with a photographing function. Fig. 2 is a sectional view along line II-II of Fig. 1, and in Fig. 2, some elements are omitted so as to simplify the drawing. In the embodiment, the binocular telescope has a casing 10, which comprises a main casing section 10A and a movable casing section 10B.

A pair of telescopic optical systems (or observation optical systems) 12R and 12L are provided in the casing 10. The telescopic optical systems 12R and 12L have a symmetrical

structure, and are used for a right telescopic optical system and a left telescopic optical system. The right telescopic optical system 12R is mounted in the main casing section 10A, and contains an objective lens system 13R, an erecting prism system 14R, and an ocular lens system 15R. An observation window 16R is formed in a front wall of the main casing section 10A, and is aligned with the objective lens system 13R. The left telescopic optical system 12L is mounted in the movable casing section 10B, and contains an objective lens system 13L, an erecting prism system 14L, and an ocular lens system 15L. An observation window 16L is formed in a front wall of the movable casing section 10B, and is aligned with the objective lens system 13L.

Note that for simplicity of explanation, in the following description, front and back are respectively defined as a side of the objective lens system and a side of the ocular lens system, relative to the pair of telescopic optical systems 12R and 12L, and right and left are respectively defined as the right side and the left side when facing the ocular lens systems 15R and 15L.

The movable casing section 10B is slidably engaged with the main casing section 10A such that the movable casing section 10B can be linearly moved relative to the main casing section 10A. Namely, the movable casing section 10B is movable between a retracted position shown in Figs. 1 and 2,

and a maximum-extended position in which the movable casing section 10B is pulled out from the retracted position, shown in Figs. 3 and 4. A suitable friction force acts on the sliding surfaces of both the casing sections 10A and 10B, and thus a certain extension or contraction force must be exerted on the movable casing section 10B before the movable casing section 10B can be extended from or contracted onto the main casing section 10A. Thus, it is possible for the movable casing section 10B to hold or stay still at an optical position between the fully retracted position (Figs. 1 and 2) and the maximum-extended position (Figs. 3 and 4), due to the suitable friction force acting on the sliding surface of both the casing sections 10A and 10B.

As understood from the comparison between Figs. 1 and 2 and Figs. 3 and 4, when the movable casing section 10B is pulled out from the main casing section 10A, the left telescopic optical system 12L is moved together with the movable casing section 10B, while the right telescopic optical system 12R is held in the main casing section 10A. Thus, by positioning the movable casing section 10B at an arbitrary extended position relative to the main casing section 10A, the distance between the optical axes of the ocular lens systems 15R and 15L, i.e., the interpupillary distance is adjusted. When the movable casing section 10B is set at the retracted position relative to the main casing

section 10A, the distance between the telescopic optical systems 12R and 12L becomes the minimum (Figs. 1 and 2), and when the movable casing section 10B is set at the maximum-extended position relative to the main casing section 10A, the distance between the telescopic optical systems 12R and 12L becomes the maximum (Figs. 3 and 4).

The objective lens system 13R of the right telescopic optical system 12R is housed in a lens barrel 17R, which is mounted at a fixed position relative to the main casing section 10A, and the erecting prism system 14R and the ocular lens system 15R can be moved back and forth with respect to the objective lens system 13R, so that the right telescopic optical system 12R can be focused. Similarly, the objective lens system 13L of the left telescopic optical system 12L is housed in a lens barrel 17L, which is mounted at a fixed position relative to the movable casing section 10B, and the erecting prism system 14L and the ocular lens system 15L can be moved back and forth with respect to the objective lens system 13L, so that the left telescopic optical system 12L can be focused.

The lens barrel 17R has a cylindrical portion 18R, in which the objective lens system 13R is housed, and an attaching base 19R integrally formed under the cylindrical portion 18R. The attaching base 19R has an inside attaching portion 19R' extending toward the center of the casing 10 from

the cylindrical portion 18R, and an outside attaching portion 19R" extending toward the outside of the casing 10 from the cylindrical portion 18R. The inside attaching portion 19R' is a side block portion having a relatively large thickness, and the outside attaching portion 19R" is a flat portion.

Similarly, the lens barrel 17L has a cylindrical portion 18L, in which the objective lens system 13L is housed, and an attaching base 19L integrally formed under the cylindrical portion 18L. The attaching base 19L has an inside attaching portion 19L' extending toward the center of the casing 10 from the cylindrical portion 18L, and an outside attaching portion 19L" extending toward the outside of the casing 10 from the cylindrical portion 18L. The inside attaching portion 19L' is a side block portion having a relatively large thickness, and the outside attaching portion 19L" is a flat portion.

To perform the interpupillary distance adjusting operation and the focusing operation described above, an optical system mount plate 20 shown in Fig. 5 is provided on a bottom side of the casing 10. Note that, in Figs. 1 and 3, the optical system mount plate 20 is omitted for the simplicity of the drawings.

The optical system mount plate 20 is composed of a rectangular plate 20A, fixed to the main casing section 10A, and a slide plate 20B slidably disposed on the rectangular plate 20A and fixed to the movable casing section 10B. The

rectangular plate 20A and the slide plate 20B are made of appropriate metal material, preferably, a light metal, such as aluminum or aluminum alloy.

The slide plate 20B has a rectangular portion 22, having approximately the same breadth as the rectangular plate 20A, and an extending portion 24, integrally connected to and extending rightward from the rectangular portion 22. The attaching base 19R of the lens barrel 17R is fixed at a predetermined position on the rectangular plate 20A, and the attaching base 19L of the lens barrel 17L is fixed at a predetermined position on the rectangular portion 22 of the slide plate 20B. Note that, in Fig. 5, the fixed position of the attaching base 19R of the lens barrel 17R is indicated as an area enclosed by chain double-dashed line 25R, and the fixed position of the attaching base 19L of the lens barrel 17L is indicated as an area enclosed by chain double-dashed line 25L.

A pair of guide slots 26 are formed in the rectangular portion 22 of the slide plate 20B, and another guide slot 27 is formed in the extending portion 24. A pair of guide pins 26', slidably engaged with the guide slots 26, and guide pin 27', slidably engaged with the guide slot 27, are fixed on the rectangular plate 20A. The guide slots 26 and 27 are parallel to each other, and extend in the right and left direction by the same length. The length of each of the guide

slots 26 and 27 corresponds to a movable distance of the movable casing section 10B relative to the main casing section 10A, i.e., the distance between the retracted position of the movable casing section 10B (Figs. 1 and 2) and the maximum-extended position of the movable casing section 10B (Figs. 3 and 4).

As understood from Figs. 2 and 4, the optical system mount plate 20 is placed in the casing 10, and separated from the bottom of the casing 10 to form a space therein. The rectangular plate 20A is fixed to the main casing section 10A, and the slide plate 20B is fixed to the movable casing section 10B. Note that, for fixing the slide plate 20B to the movable casing section 10B, a flange 28, extending along the left side edge of the rectangular portion 22, is provided, and fixed on a partition 29 formed in the movable casing section 10B.

Figs. 6 and 7 show a right mount plate 30R and a left mount plate 30L. The right mount plate 30R is provided for mounting the erecting prism system 14R of the right telescopic optical system 12R, and the left mount plate 30L is provided for mounting the erecting prism system 14L of the left telescopic optical system 12L. Upright plates 32R and 32L are provided along the rear peripheries of the right and left mount plates 30R and 30L. As shown in Figs. 1 and 3, the right ocular lens system 15R is attached to the upright plate 32R, and the left ocular lens system 15L is attached to the upright

plate 32L.

As shown in Figs. 6 and 7, the right mount plate 30R is provided with a guide shoe 34R secured to the underside thereof in the vicinity of the right side edge thereof. The guide shoe 34R is formed with a groove 36R, which slidably receives a right side edge of the rectangular plate 20A, as shown in Fig. 7. Similarly, the left mount plate 30L is provided with a guide shoe 34L secured to the underside thereof in the vicinity of the left side edge thereof. The guide shoe 34L is formed with a groove 36L, which slidably receives a right side edge of the rectangular plate 20B, as shown in Fig. 7.

Note that since Fig. 7 is a sectional view along line VII-VII of Fig. 6, the optical system mount plate 20 should not be indicated in Fig. 7. Nevertheless, for the simplicity of the explanation, in Fig. 7, the optical system mount plate 20 is indicated as a section along line VII-VII of Fig. 5, and the guide shoes 34R and 34L are indicated as sectional views.

As shown in Figs. 6 and 7, the right mount plate 30R has a side wall 38R provided along a left side edge thereof, and a lower portion of the side wall 38R is formed as a swollen portion 40R having a through bore for slidably receiving a guide rod 42R. The front end of the guide rod 42R is inserted in a hole 43R formed in the inside attaching portion 19R' of

the attaching base 19R, and is fixed thereto. The rear end of the guide rod 42R is inserted in a hole 45R formed in an upright fragment 44R integrally formed on a rear edge of the rectangular plate 20A, and is fixed thereto (see Fig. 5). Note that, in Fig. 5, the upright fragment 44R is indicated as a sectional view so that the hole 45R is observed, and in Figs. 1 and 3, the rear end of the guide rod 42R is inserted in the hole 45R of the upright fragment 44R.

Similarly, the left mount plate 30L has a side wall 38L provided along a right side edge thereof, and a lower portion of the side wall 38L is formed as a swollen portion 40L having a through bore for slidably receiving a guide rod 42L. The front end of the guide rod 42L is inserted in a hole 43L formed in the inside attaching portion 19L' of the attaching base 19L, and is fixed thereto. The rear end of the guide rod 42L is inserted in a hole 45L formed in an upright fragment 44L integrally formed on a rear edge of the rectangular plate 20B, and is fixed thereto. Note that, similarly to the upright fragment 44R, in Fig. 5, the upright fragment 44L is indicated as a sectional view so that the hole 45L is observed, and in Figs. 1 and 3, the rear end of the guide rod 42L is inserted in the hole 45L of the upright fragment 44L.

The objective lens system 13R of the right telescopic optical system 12R is disposed at a stationary position in front of the right mount plate 30R. Therefore, when the right

mount plate 30R is moved back and forth along the guide rod 42R, the distance between the objective lens system 13R and the erecting prism system 14R is adjusted, so that a focusing operation of the right telescopic optical system 12R is performed. Similarly, since the objective lens system 13L of the left telescopic optical system 12L is disposed at a stationary position in front of the left mount plate 30L, by moving the left mount plate 30L back and forth along the guide rod 42L, the distance between the objective lens system 13L and the erecting prism system 14L is adjusted, so that a focusing operation of the left telescopic optical system 12L is performed.

In order to simultaneously move the right and left mount plates 30R and 30L along the guide rods 42R and 42L such that a distance between the right and left mount plates 30R and 30L is variable, the mount plates 30R and 30L are interconnected to each other by an expandable coupler 46, as shown in Figs. 6 and 7.

In particular, the expandable coupler 46 includes a rectangular lumber-like member 46A, and a forked member 46B in which the lumber-like member 46A is slidably received. The lumber-like member 46A is securely attached to the underside of the swollen portion 40R of the side wall 38R at the forward end thereof, and the forked member 46B is securely attached to the underside of the swollen portion 40L of the

side wall 38L at the forward end thereof. Both members 46A and 46B have a length which is greater than the distance of movement of the movable casing section 10B, between its retracted position (Figs. 1 and 2) and its maximum extended position (Figs. 3 and 4). Namely, even though the movable casing section 10B is extended from the retracted position to the maximum extended position, slidable engagement is maintained between the members 46A and 46B.

With reference to Fig. 8, there is shown a vertical sectional view along line VIII-VIII of Fig. 1. As understood from Figs. 2, 4, and 8, an inner frame 48 is housed in the casing 10, and is fixed to the main casing section 10A and the rectangular plate 20A. The inner frame 48 has a central portion 48C, a right wing portion 48R extending from the central portion 48C rightward, a vertical wall 48S extending from a right periphery of the right wing portion 48R downward, and a left wing portion 48L extending from the central portion 48C leftward.

As shown in Fig. 8, a bore 50 is formed in a front end portion of the central portion 48C, and is aligned with a circular window 51 formed in a front wall of the main casing section 10A. A recess 52 is formed in a rear portion in the central portion 48C, and a rectangular opening 54 is formed in a bottom of the recess 52. A top wall of the main casing section 10A is provided with an opening for exposing the

recess 52, and the opening is closed by a cover plate 55 which can be removed from the opening.

A tubular assembly 56 is assembled in the recess 52 while the cover plate 55 is removed. The tubular assembly 56 has a rotary wheel cylinder (i.e., rotary wheel member) 57 and a lens barrel 58 disposed coaxially in the rotary wheel cylinder 57. The rotary wheel cylinder 57 is rotatably supported in the recess 52, and the lens barrel 58 can be moved along the central axis thereof while the lens barrel 58 is kept still so as not to rotate about the central axis. After assembling the tubular assembly 56, the cover plate 55 is fixed to cover the recess 52. A rotary wheel 60 is provided on the rotary wheel cylinder 57. The rotary wheel 60 has an annular projection formed on an outer surface of the rotary wheel cylinder 57, and the rotary wheel 60 exposes outside the top wall of the main casing section 10A through an opening 62 formed in the cover plate 55.

Four helicoid cam grooves 64, spaced at a constant interval with respect to each other, are formed on an outer surface of the rotary wheel cylinder 57, and an annular member 66 is threadingly fit on the helicoid cam grooves 64. Namely, four projections, engaged with the helicoid cam grooves 64 of the rotary wheel cylinder 57, are formed on an inner wall of the annular member 66, and disposed at a constant interval. Thus, the annular member 66 is threadingly fit on the helicoid

cam grooves 64 through the projections.

A flat surface is formed on an outer periphery of the annular member 66, and is slidably engaged with an inner wall of the cover plate 55. Namely, when the rotary wheel cylinder 57 is rotated, the annular member 66 is not rotated due to the engagement of the flat surface and the inner wall of the cover plate 55, and is kept in a non-rotational state. Thus, when the rotary wheel cylinder 57 is rotated, the annular member 66 is moved along the central axis of the rotary wheel cylinder 57 due to the threading contact of the projections and the helicoid cam grooves 64, and the moving direction depends on the rotational direction of the rotary wheel cylinder 57.

A tongue 67 is projected from the annular member 66, and is positioned at an opposite side of the flat surface of the annular member 66. As shown in Fig. 8, the tongue 67 is projected from the rectangular opening 54 of the central portion 48C, and is inserted in a hole 47 formed in the rod member 46A. Therefore, when a user rotates the rotary wheel cylinder 57 by contacting the exposed portion of the rotary wheel 60 with a finger, for example, the annular member 66 is moved along the central axis of the rotary wheel cylinder 57, as described above, so that the mount plates 30R and 30L are moved along the optical axes of the telescopic optical systems 12R and 12L. Thus, the rotational movement of the

rotary wheel 60 is converted into linear movements of the erecting prism systems 14R and 14L, and the ocular lens systems 15R and 15L, so that the telescopic optical systems 12R and 12L can be focused.

In this embodiment, the pair of telescopic optical systems 12R and 12L are designed, for example, in such a manner that, when the distance from each of the erecting prism systems 14R and 14L, and the ocular lens systems 15R and 15L to each of the objective lens systems 13R and 13L is the shortest, the pair of telescopic optical systems 12R and 12L focus on an object located at a distance between 40 meters ahead of the binocular telescope and infinity, and when observing an object between 2 meters and 40 meters ahead of the binocular telescope, the erecting prism systems and the ocular lens systems are separated from the objective lens systems so as to focus on the object. Namely, when the erecting prism systems are separated from the objective lens systems by the maximum distance, the pair of telescopic optical systems focus on an object located at a distance approximately 2 meters ahead of the binocular telescope.

A photographing optical system 68 is provided in the lens barrel 58, which is coaxially disposed in the rotary wheel cylinder 57. The photographing optical system 68 has a first lens group 68A and a second lens group 68B. A circuit board 70 is attached on an inner surface of a rear end wall

of the main casing section 10A. A solid-state imaging device such as a CCD 72 is mounted on the circuit board 70, and a light-receiving surface of the CCD 72 is aligned with the photographing optical system 68. An opening is formed in a rear end portion of the central portion 48C of the inner frame 48, and is aligned with the optical axis of the photographing optical system 68. An optical low-pass filter 74 is fit in the opening. Thus, the binocular telescope of this embodiment has the same photographing function as a digital camera, so that an object image obtained by the photographing optical system 68 is formed on the light-receiving surface of the CCD 72 as an optical image, which is photoelectrically converted into one frame's worth of image signals.

In Figs. 1 through 4, the optical axis of the photographing optical system 68 is indicated by the reference OS, and the optical axes of the right and left telescopic optical systems 12R and 12L are indicated by references OR and OL. The optical axes OR and OL are parallel to each other, and to the optical axis OS of the photographing optical system 68. As shown in Figs. 2 and 4, the optical axes OR and OL define a plane P which is parallel to the optical axis OS of the photographing optical system 68. The right and left telescopic optical systems 12R and 12L can be moved parallel to the plane P, so that the distance between the optical axes OR and OL, i.e., the interpupillary distance, can be adjusted.

The binocular telescope with a photographing function of the embodiment is constructed, similar to the usual digital camera, in such a manner that a near object, which is situated at 2 meters ahead of the binocular telescope, for example, can be photographed, and due to this, a focusing mechanism is assembled between the rotary wheel cylinder 57 and the lens barrel 58. Namely, four helicoid cam grooves 75 are formed on an inner wall of the rotary wheel cylinder 57, and four projections, which are cam followers engaged with the helicoid cam grooves 75, are formed on an outer wall of the lens barrel 58.

On the other hand, the front end of the lens barrel 58 is inserted in the bore 50, and a bottom portion of the front end is formed with a key groove 76, which extends from the front end of the lens barrel 58 in the longitudinal direction by a predetermined length. A hole is formed in a bottom portion of the front end of the inner frame 48, and a pin 77 is planted in the hole to engage with the key groove 76. Thus, by the engagement of the key groove 76 and the pin 77, the rotation of the lens barrel 58 is prevented.

Therefore, when the rotary wheel cylinder 57 is rotated by an operation of the rotary wheel 60, the lens barrel 58 is moved along the optical axis of the photographing optical system 68. Thus, the helicoid cam grooves 75 formed on the inner wall of the rotary wheel cylinder 57 and the projection

or cam follower formed on the outer wall of the lens barrel 58 form a movement-conversion mechanism that converts a rotational movement of the rotary wheel 57 into a linear movement or focusing movement of the lens barrel 58.

Fig. 9 shows a developing view in which the helicoid cam grooves 64 and 75 formed on the outer wall and the inner wall of the rotary wheel cylinder 57 are developed in a flat plane. In this drawing, the projection 64P of the annular member 66 is engaged with the helicoid cam groove 64, and the projection 75P of the lens barrel 58 is engaged with the helicoid cam groove 75.

As understood from Fig. 9, the helicoid cam groove 64 formed on the outer wall of the rotary wheel cylinder 57 and the helicoid cam groove 75 formed on the inner wall of the rotary wheel cylinder 57 are inclined in the opposite direction to each other. Namely, when the rotary wheel cylinder 57 is rotated in such a manner that the erecting prism systems 14R and 14L and the ocular lens systems 15R and 15L are separated from the objective lens systems 13R and 13L, the lens barrel 58 is moved to separate from the CCD 72. Due to this, an image of a near object can be focused on the light-receiving surface of the CCD 72. The shape of the helicoid cam groove 64 of the outer wall of the rotary wheel cylinder 57 and the shape of the helicoid cam groove 75 of the inner wall are different from each other in accordance

with the optical characteristics of the pair of telescopic optical systems 12R and 12L and the photographing optical system 68.

When the pair of telescopic optical systems 12R and 12L focus on an object at infinity, which is further than 40 meters, i.e., when the erecting prism systems 14R and 14L and the ocular lens systems 15R and 15L are set at their closest position to the objective lens systems 13R and 13L, the lens barrel 58 is positioned at its closest position to the light-receiving surface of the CCD 72, and each of the projections 64P and 75P are engaged with an end, corresponding to the infinity, of each of the helicoid cam grooves 64 and 75.

When a near object, which is situated from 2 meters to 40 meters ahead of the binocular telescope, is to be observed by the pair of telescopic optical systems 12R and 12L, the rotary wheel 60 is rotated so that the erecting prism systems 14R and 14L and the ocular lens systems 15R and 15L are separated from the objective lens systems 13R and 13L. Thus, the telescopic optical systems 12R and 12L focus on the object, and the photographing optical system 68 is operated in association with the telescopic optical systems 12R and 12L to focus on the object. Namely, the helicoid cam grooves 64 and 75 are formed in such a manner that the photographing optical system 68 focuses on the object when the pair of

telescopic optical systems 12R and 12L focus on the object due to the rotation of the rotary wheel 57.

Thus, if an observed object is observed by the pair of telescopic optical systems 12R and 12L as a focused image, an image to be photographed, corresponding to the observed object, is formed on the light-receiving surface of the CCD 72 as a focused image. However, even if the observed object is observed through the pair of telescopic optical systems 12R and 12L in an in-focus state, the telescopic optical systems 12R and 12L are not necessarily focused with the same dioptric power. This is because, as described above, human eyes have the ability to adjust their focusing state, so that the dioptric power, with which the object is observed, is changed depending upon the human. Namely, even if the dioptric power of the pair of the telescopic optical systems 12R and 12L is offset from the proper value, the human can observe the object as a focused image through the pair of the telescopic optical systems 12R and 12L.

For resolving the problem described above, in the embodiment, as shown in Figs. 1 and 3, one of the pair of the telescopic optical systems 12R and 12L, i.e., the right telescopic optical system 12R, for example, is provided with a reticle 78R. In detail, the upright plate 32R of the right mount plate 30R is provided with an aperture 79R which defines a field of view of the right telescopic optical system 12R

as a rectangle, and the reticle 78R is provided in the aperture 79R. The reticle 78R is formed by applying a pair of glass plates 80A and 80B to each other, as shown in Fig. 10. As shown in Fig. 11, a rectangular field of view, defined by the aperture 79R, is formed on each of the glass plates 80A and 80B, and a cross index 81 is formed at the center of the plane formed between the glass plates 80A and 80B.

The reticle 78R is formed as follows: First, the cross index 81 is formed on one of the glass plates 80A and 80B (the glass plate 80B, for example), by vacuum-evaporating metal, such as aluminum. Then, for protecting the cross index 81, the other glass plate 80A is applied to a surface of the glass plate 80B, on which the cross index 81 is formed, so that the reticle 78R is formed. Note that the boundary plane between the glass plates 80A and 80B (i.e., the cross index 81) is placed to coincide with an aperture plane of the aperture 79R (i.e., the front focal point of the ocular optical system 15R).

When the reticle 78R is mounted in the right telescopic optical system 12R, an optical path difference is generated between the optical distance of the right telescopic optical system 12R and the optical distance of the left telescopic optical system 12L. Therefore, for coinciding both the optical distances with each other, in the left telescopic optical system 12L, an optical element 78L is provided in an

aperture 79L formed on the upright plate 32R of the left mount plate 30L. The optical element 78L is formed by applying or joining a pair of glass plates, having the same optical characteristics as the pair of glass plates 80A and 80B forming the reticle 78R, to each other, but a cross index is not formed on a boundary plane between the pair of glass plates of the optical element 78L. Note that the optical element 78L is not necessarily formed by joining a pair of glass plates, but may be integrally formed, if the thickness corresponding to the optical path difference is correct, taking the index of refraction into consideration. Further, the relative position between the objective lens system 13L and the ocular lens system 15L may be shifted by the optical path difference with respect to the right telescopic optical system 12R.

Each user has different sight characteristics, and even for the same user, the sight in the right and left eyes is different. Therefore, it is necessary to adjust the dioptric powers of the ocular lens systems 15R and 15L relative to the aperture plane of the apertures 79R and 79L in accordance with the sight of the right and left eyes of the user. Thus, for adjusting the dioptric power of each of the ocular lens systems 15R and 15L, the distances of the ocular lens systems 15R and 15L relative to the aperture plane of the apertures 79R and 79L can be adjusted.

Namely, as shown in Figs. 1 and 3, cylindrical portions

82R and 82L enclosing the apertures 79R and 79L are formed on the upright plates 32R and 32L of the right and left mount plates 30R and 30L, and female screws are formed on the inner surfaces of the cylindrical portions 82R and 82L. Male screws are formed on the outer surfaces of the lens barrels 83R and 83L holding the ocular lens systems 15R and 15L, and the lens barrels 83R and 83L are threaded in the cylindrical portions 82R and 82L. Thus, by rotating each of the lens barrels 83R and 83L in each of the cylindrical portions 82R and 82L, the distance of each of the ocular lens systems 15R and 15L relative to each of the aperture planes of the apertures 79R and 79L, i.e., the dioptric power of each of the ocular lens systems 15R and 15L, can be adjusted. Note that, since grease having a high viscosity is provided between the cylindrical portions 82R and 82L and the lens barrels 83R and 83L, the lens barrels 83R and 83L will not rotate unexpectedly.

In the dioptric power adjustment of the right ocular lens system 15R, first, the user looks or observes through the ocular lens system 15R with the right eye. If the cross index 81 is observed in an out-of-focus state, the user rotates the lens barrel 83R to adjust the position of the ocular lens system 15R until the cross index 81 can be observed in an in-focus state. Note that, in the embodiment, although the left ocular lens system 15L is not provided with a cross

index, the dioptric power of the left ocular lens system 15L can be adjusted by rotating the lens barrel 83L.

When each of the telescopic optical systems 12R and 12L focuses on infinity, although the rear focal points of the objective lens systems 13R and 13L are approximately coincident with the front focal points of the ocular lens systems 15R and 15L, regarding a near object, the rear focal points of the objective lens systems 13R and 13L are offset from the front focal points of the ocular lens systems 15R and 15L. Therefore, it is necessary that the positions of the ocular lens systems 15R and 15L relative to the objective lens systems 13R and 13L are adjusted so that the rear focal points of the objective lens systems 13R and 13L are coincident with the in-focus position, i.e., the front focal points of the ocular lens systems 15R and 15L.

In this focusing operation, if the reticle 78R is provided in the right telescopic optical system 12R, the user adjusts the dioptric power so that the cross index 81 is easily observed, and observes the object in an in-focus state, and thus, the eyes of the user function to focus on the observed object. Therefore, when the user's eyes focus on the observed object through the pair of telescopic optical systems 12R and 12L, an image of the observed object is formed on the light-receiving surface of the CCD 72, as a focused object image through the photographing optical system 68.

Namely, the pair of telescopic optical systems 12R and 12L are utilized as a focusing device for the photographing optical system 68.

The inventors conducted a focusing test, using a test model of a binocular telescope with a photographing function, to examine whether, when an observer observes an object through the pair of telescopic optical systems 12R and 12L, the eyes of the observer focus on the object image formed exactly on the plane of the cross index 81 (i.e., the in-focus position). According to the result of the focusing test, it unexpectedly turned out that each of the observer's eyes focus on the object image at a position slightly offset from the in-focus position.

The details are as follows. For the focusing test, six subjects were chosen. Each of the subjects carried out a focusing operation so that an observed object, more than 40 meters ahead of the test model of the binocular telescope with a photographing function, was observed as a focused image. And, when each of the subjects recognized that the object image was focused, the position of focus of each of the objective lens systems 13R and 13L was measured. The measured position was compared with the position of the cross index 81, so that the difference was obtained as a dioptric power difference. Similar measurements were performed regarding an observed object which was positioned 10, 5, and

2.5 meters ahead of the test model.

Fig. 12 is a graph showing the measurement results of the test. In the graph, the axis of abscissas indicates the distance from the test model to the observed object, and the axis of ordinates indicates the dioptric power (D). The dioptric power is given in diopters. Further, in the graph, the measurement results for the six subjects are indicated by ●, ○, ■, □, ▲, and △. As understood from Fig. 12, although the subject observes the cross index 81, the eyes of the subject focus on the observed image formed at a position slightly offset from the plane of the cross index 81 (i.e., the in-focus position). Namely, it turns out that the observed image is offset to the short distance side, i.e., a minus diopter, relative to the cross index 81.

As a matter of fact, the dioptric power difference can be ignored because the photographing optical system 68 has a depth of focus. However, when a photographed image having the better sharpness than usual is required, the movement of the lens barrel 58 of the photographing optical system 68 should be adjusted so that the dioptric power difference is cancelled.

In detail, as understood from Fig. 12, although the dioptric power difference of each of the subjects has a different value, the tendency of the dioptric power difference is similar. Therefore, after obtaining an

arithmetic mean of measured dioptric power differences, the movement of the lens barrel 58 can be adjusted in such a manner that the mean value of the measured dioptric power differences is cancelled. Namely, as shown in Fig. 13, the shape of the helicoid cam groove 75 is modified based on the mean value, so that the movement of the lens barrel 58 is adjusted in accordance with the dioptric power difference in the focusing operation, and thus, a sharper photographed image can be obtained. Note that the broken line of the helicoid cam groove 75 shown in Fig. 13 corresponds to that shown in Fig. 9.

Thus, according to the helicoid cam groove 75 having the shape shown in Fig. 13, when the observed object to be focused is at a relatively short distance, the photographing optical system 68 is positioned at a front side (the object side, i.e., the left side in Fig. 13) in comparison with a theoretical position (i.e., a position determined by the cam groove shown in Fig. 9), and is offset to a minus diopter side, similarly to the offset of the dioptric power shown in Fig. 12.

Thus, a measured dioptric power difference between a first dioptric power of a combination of an eye of the user and the ocular lens system 15R of the telescopic optical system 12R, focusing on the reticle, and a second dioptric power of a combination of the eye and the ocular lens system

15R and the objective lens system 13R of the telescopic optical system 12R, focusing on an object to be observed, is cancelled.

On the other hand, if necessary, the helicoid cam groove 75 may be changed so that the dioptric power difference of the individual is cancelled. Due to this, the binocular telescope with a photographing function is optimized for the user.

As shown in Figs. 1 through 4, a power supply circuit board 84, which is relatively heavy, is provided in a right end portion of the main casing section 10A. As shown in Figs. 2, 4, and 8, a control circuit board 85 is provided between the bottom of the main casing section 10A and the optical system mount plate 20, and is fixed on the bottom of the main casing section 10A. Electronic parts such as a CPU, a DSP, a memory, a capacitor, and so on are mounted on the control circuit board 85, and the circuit board 70 and the power supply circuit board 84 are connected to the control circuit board 85 through a flat flexible wiring cord (not shown).

In the embodiment, as shown in Figs. 2, 4, and 8, an LCD monitor 86 is disposed on an upper surface of the top wall of the main casing section 10A. The LCD monitor 86 has a flat rectangular plate shape. The LCD monitor 86 is arranged in such a manner that its front and rear sides, positioned at opposite sides, are perpendicular to the optical axis of the

photographing optical system 68, and the LCD monitor 86 is rotatable about a rotational shaft 87 provided along the front side. The LCD monitor 86 is usually folded or closed as shown by a solid line in Fig. 8. In this condition, since the display surface of the LCD monitor 86 faces an upper surface of the main casing section 10A, the display surface cannot be seen. Conversely, when a photographing operation is performed using the CCD 72, the LCD monitor 86 is rotated and raised from the folding position to a display position shown by a broken line in Fig. 8, so that the display surface of the LCD monitor 86 can be seen from the side of the ocular lens systems 15R and 15L.

The left end portion of the movable casing section 10B is divided by the partition 29, to form a battery chamber 88 in which batteries 92 are housed. As shown in Figs. 2 and 4, a lid 90 is provided in a bottom wall of the battery chamber 88. By opening the lid 90, the batteries 92 can be mounted in or removed from the battery chamber 88. The lid 90 forms a part of the movable casing section 10B, and is fixed at a closing position shown in Figs. 2 and 4 through a proper engaging mechanism.

The weight of the power supply circuit board 84 is relatively high, and similarly, the weights of the batteries 92 are relatively high. In the embodiment, two components having a relatively large weight are disposed in both ends

of the casing 10. Therefore, the weight balance of the binocular telescope with a photographing function is improved.

As shown in Figs. 1 and 3, electrode plates 94 and 96 are provided at front and rear portions of the battery chamber 88. The batteries 92 are arranged in parallel to each other in the battery chamber 88, and directed in opposite directions in the battery chamber to contact the electrode plates 94 and 96. The electrode plate 94 is electrically connected to the casing 10, and the electrode plate 96 is electrically connected to the power supply circuit board 84 through a power source cable (not shown) so that electric power is supplied from the batteries 92 to the power supply circuit board 84. The power supply circuit board 84 supplies electric power to the CCD 72 mounted on the circuit board 70, the electric parts such as the microcomputer and the memory mounted on the control circuit board 85, and the LCD monitor 84.

As shown in Fig. 1 through Fig. 4, it is possible to provide a video output terminal 102, for example, as an external connector, on the power supply circuit board 84, and in this case, a hole 104 is formed in the front wall of the main casing section 10A so that an external connector is connected to the video output terminal 102. Further, as shown in Figs. 2 and 3, a CF-card driver 106, in which a CF-card can be detachably mounted as a memory card, may be provided

below the control circuit board 85 on the bottom of the main casing section 10A.

As shown in Figs. 2, 4, and 8, the bottom of the main casing section 10A is provided with a screw-hole forming part 108. The screw-hole forming part 108 is a thick portion having a circular section, and a screw-hole 110 is formed in the thick portion, as shown in Fig. 8. The screw-hole 110 of the screw-hole forming part 108 is connected to a screw attached to a tripod head.

Although the above embodiment is a binocular telescope with a photographing function as an example of an observation optical device with a photographing function, the present invention can be applied to other optical devices, such as a monocular telescope with a photographing function.

Further, although the helicoid cam grooves 75 are formed on an inner surface of the rotary wheel cylinder 57 and the projection engaged with the helicoid cam grooves 75 is provided on an outer surface of the lens barrel 58, the helicoid cam grooves 75 may be formed on the outer surface of the lens barrel 58 and the projection may be provided on the inner surface of the rotary wheel cylinder 57.

Although the embodiments of the present invention have been described herein with reference to the accompanying drawings, obviously many modifications and changes may be made by those skilled in this art without departing from the

scope of the invention.

The present disclosure relates to subject matter contained in Japanese Patent Application No. 2002-211438 (filed on July 19, 2002) which is expressly incorporated herein, by reference, in its entirety.